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(71) Applicant(s)
Baker Hughes Incorporated
(Incorporated in USA - Delaware)
3900 Essex Lane, Suite 1200, P.O. Box 4740, Houston,
Texas 77210-4740, United States of America

(72) Inventor(s)
Darrin L Willauer
Richard Van Buskirk

(74) Agent and/or Address for Service
Murgitroyd & Company
373 Scotland Street, GLASGOW, G5 8QA,
United Kingdom

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E21B 33/127

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(56) Documents Cited
GB 2349657 A US 5868201 A US 5417122 A

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(54) Abstract Title
Intelligent through tubing bridge plug with downhole instrumentation

(57) A through tubing retrievable bridge plug comprises an inflatable element, a sensor module 30, a control module 60 and a transmitter 52. The sensor module 30 comprises at least one sensor to monitor downhole parameters such as temperature, flow rate, gamma radiation, radio waves, electromagnetic waves, or pressure either within the inflatable element or in the annuluses formed above and below the inflatable element. The transmitter 52 transmits acoustically, by radio or electro-magnetic waves or by vibration.

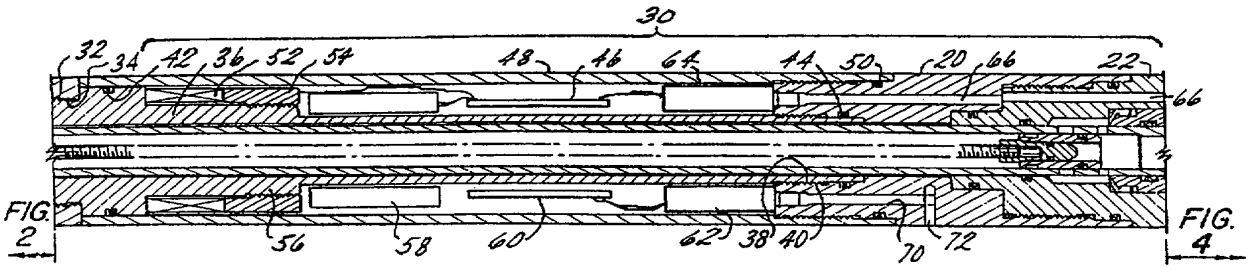

FIG. 3

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

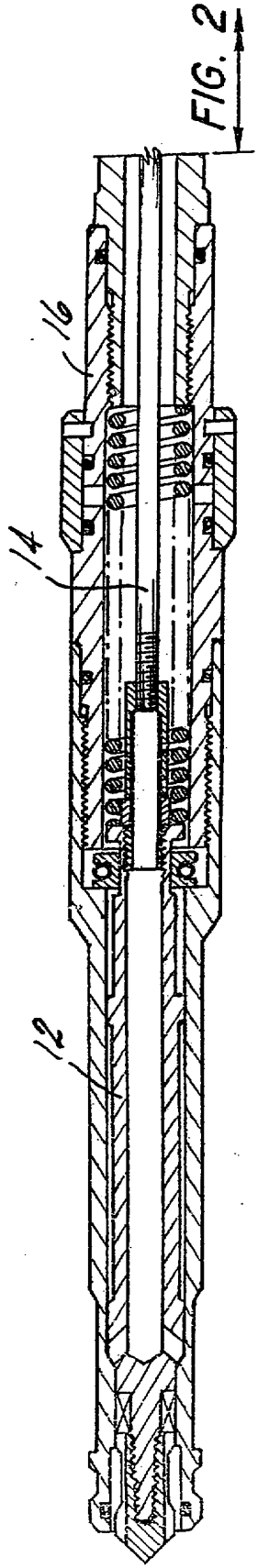

FIG. 1

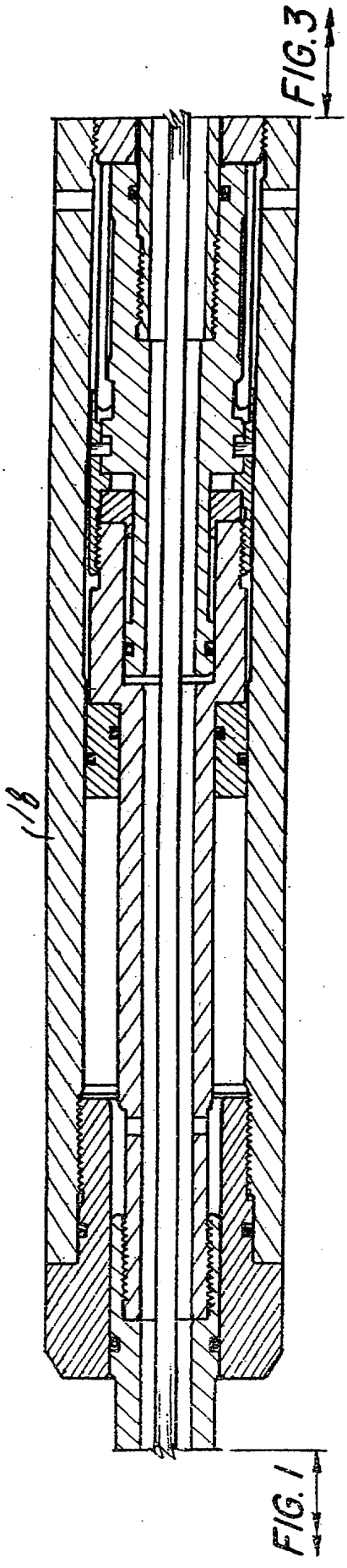

FIG. 2

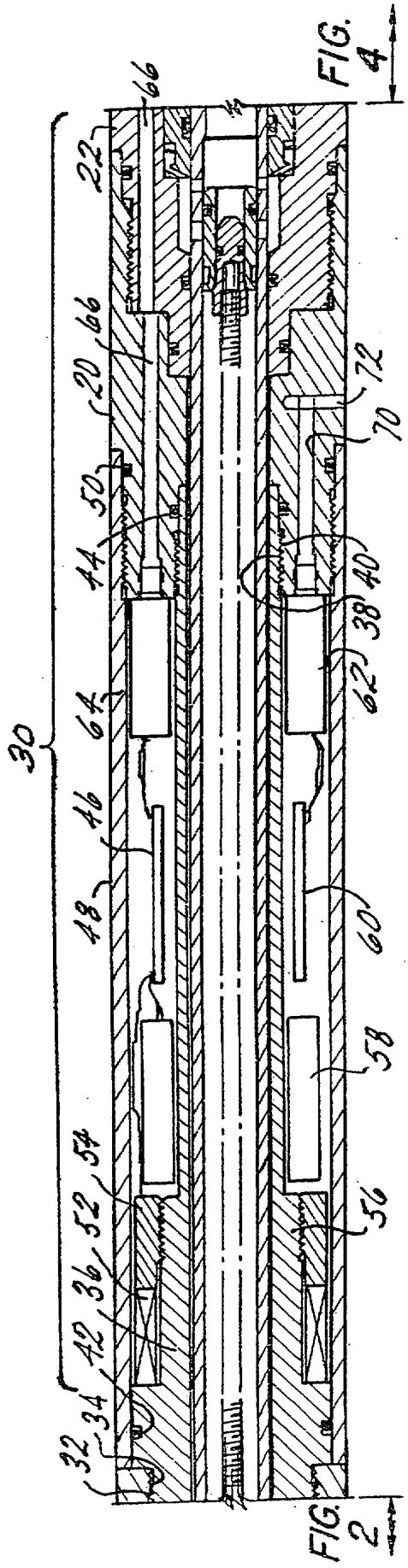

FIG. 3

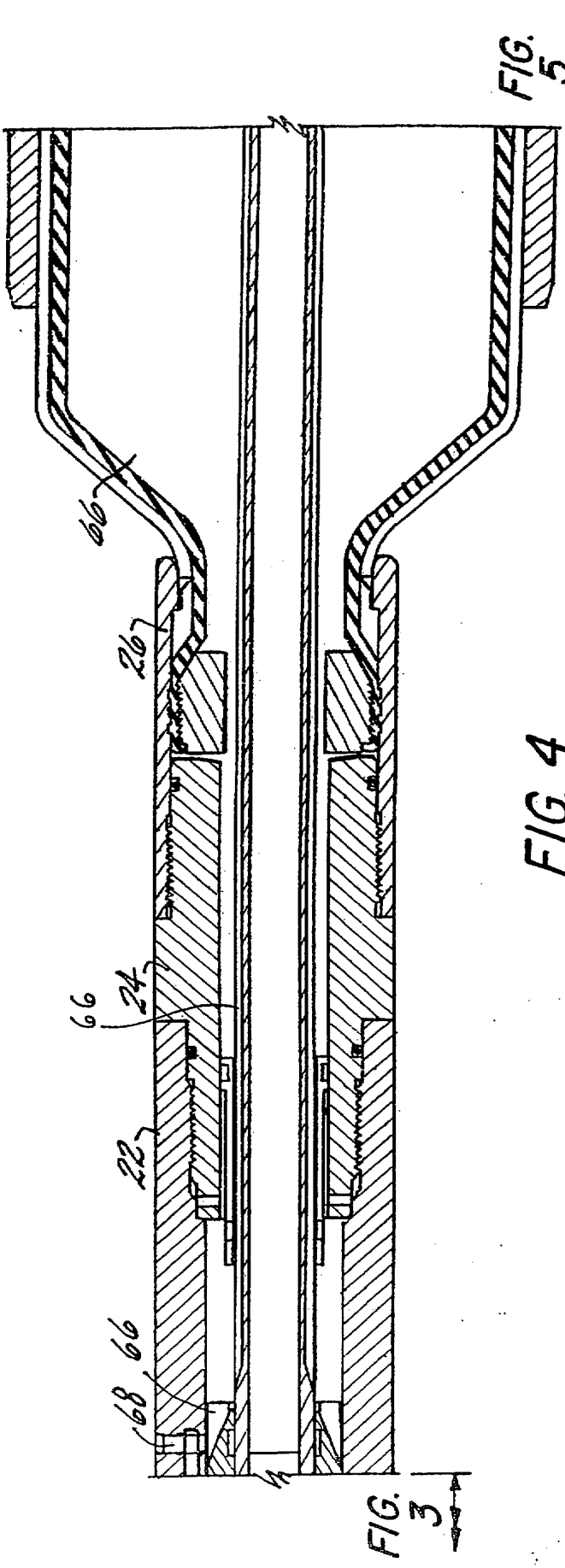

FIG. 4

FIG. 2

FIG. 4

FIG. 5

FIG. 3

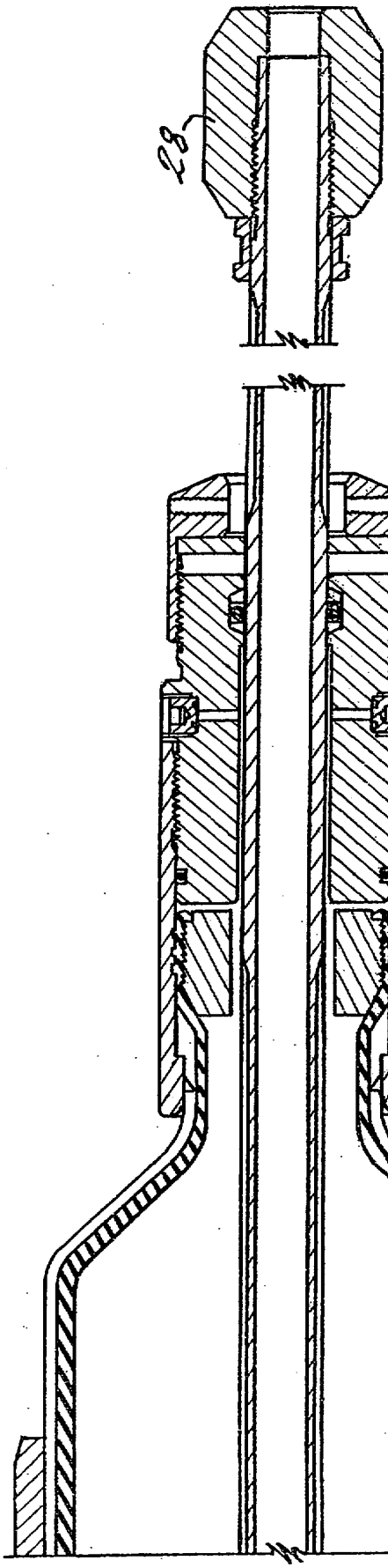

FIG. 5

FIG. 4

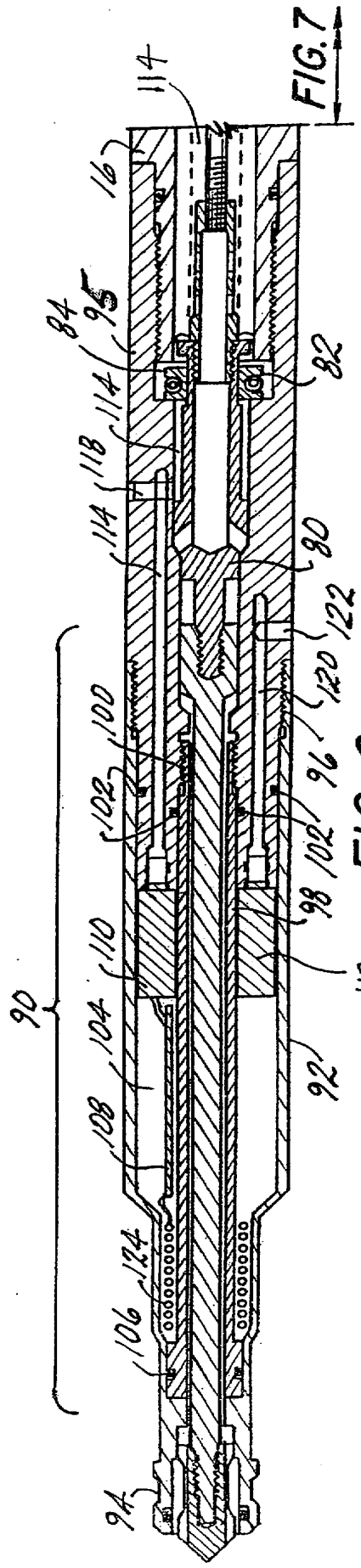
FIG. 7
114
16
84
95
82
114
118
114
80
122
120
100
102
96
102
98
110
112
90
104
92
108
124
106
94

FIG. 6

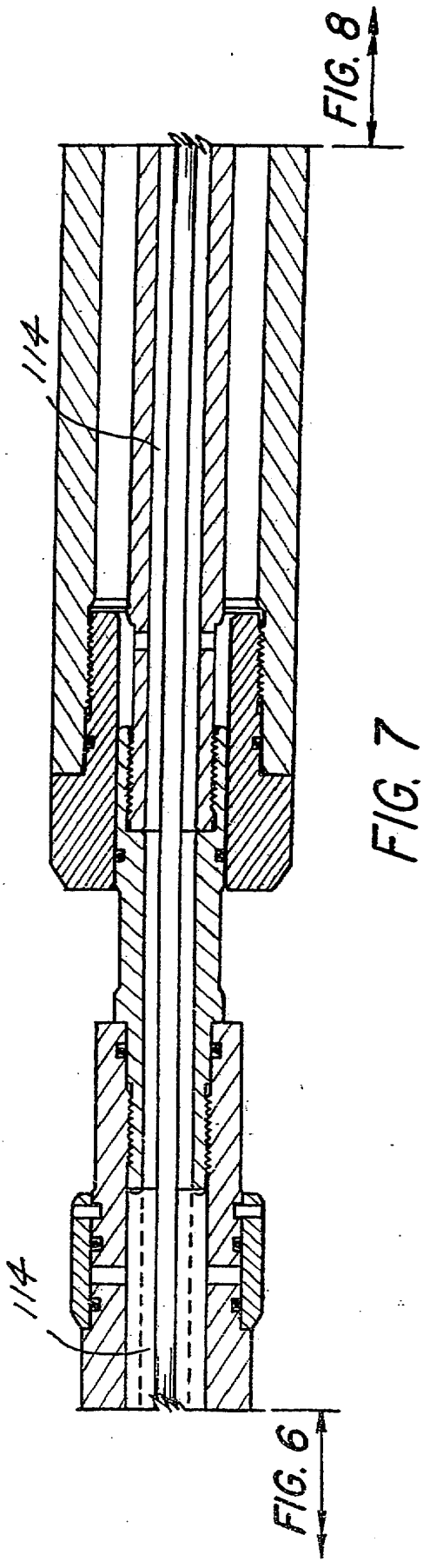
FIG. 8
114
114
FIG. 6

FIG. 7

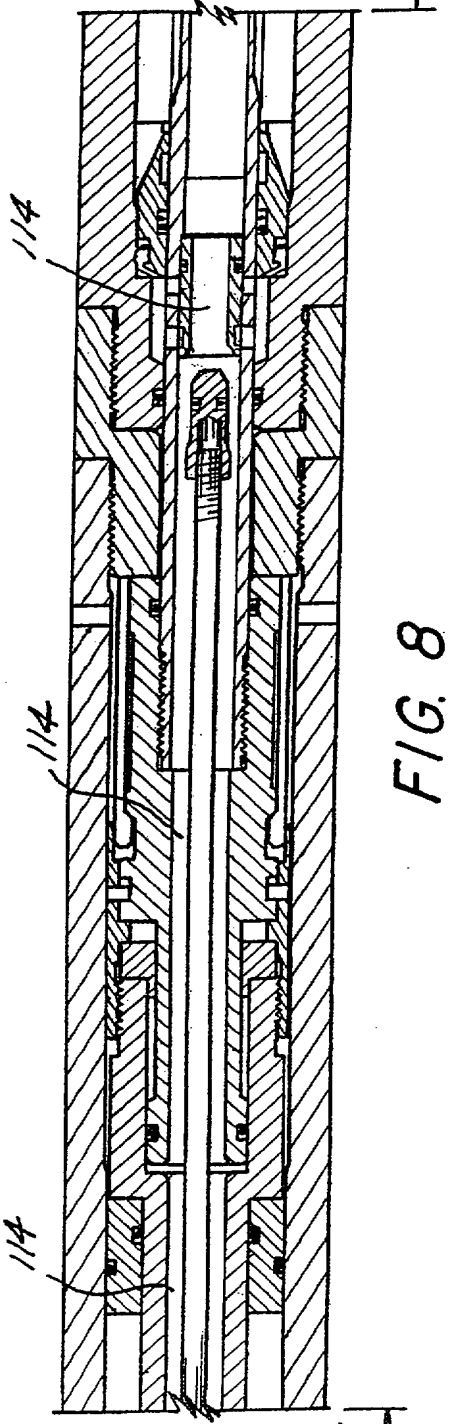

FIG. 8

FIG. 9

FIG. 7

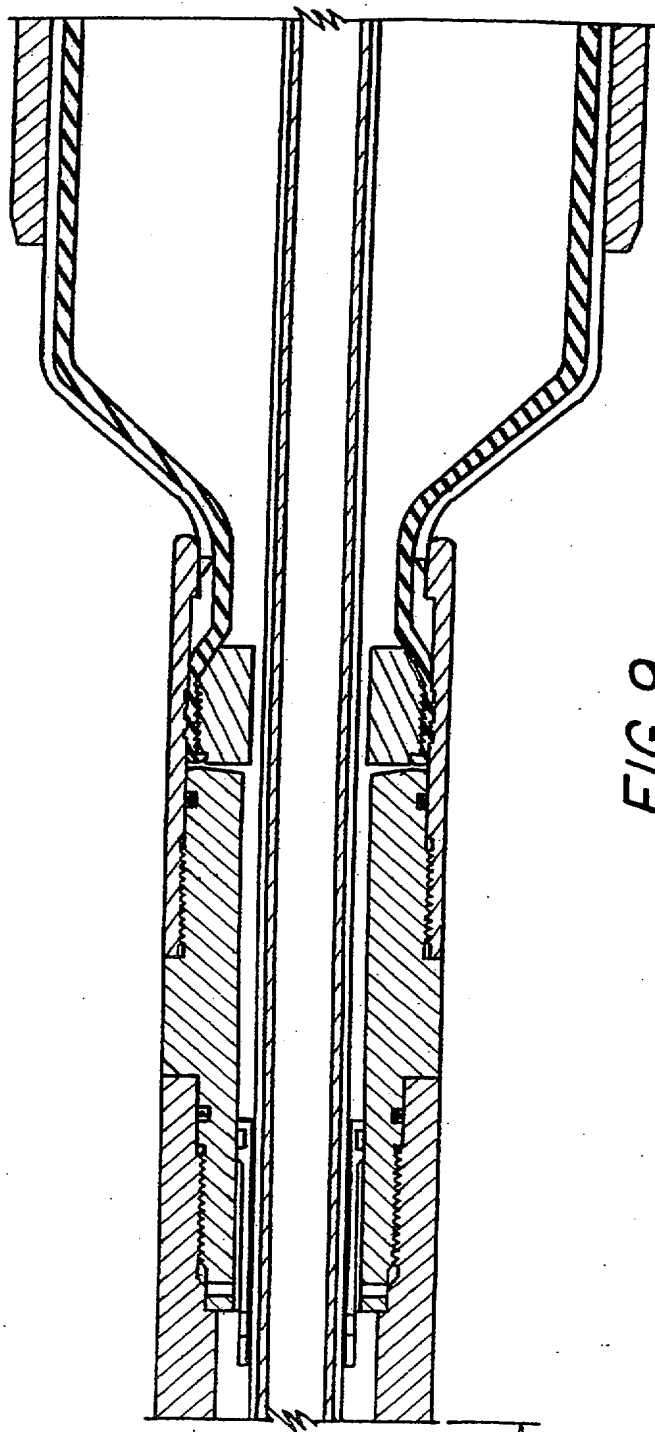

FIG. 9

FIG. 10

FIG. 8

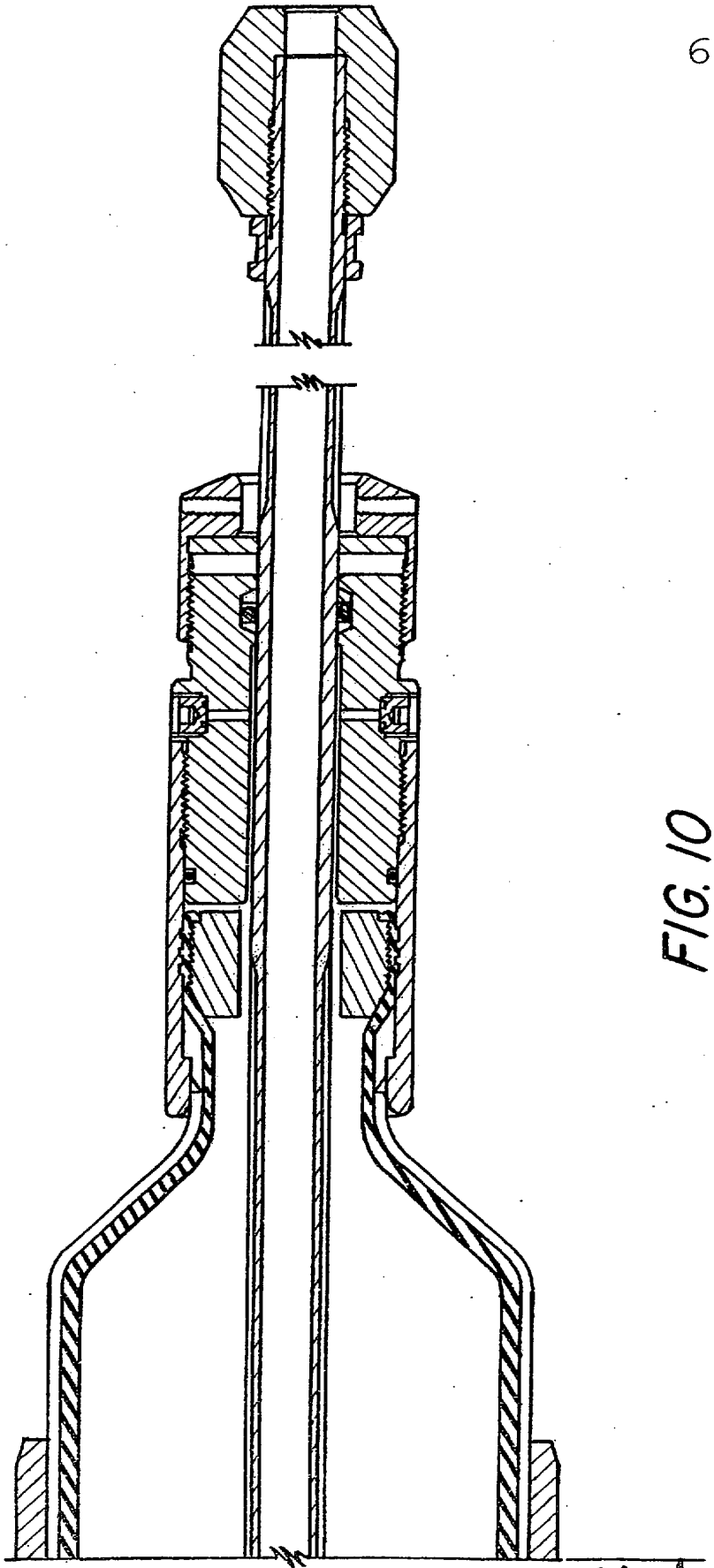

FIG. 10

FIG. 9

INTELLIGENT THROUGH TUBING BRIDGE PLUG WITH DOWNHOLE INSTRUMENTATION

BACKGROUND

Thru tubing retrievable bridge plugs provide a means of temporarily plugging selected sections of a well, without the need for pulling production tubing. Avoidance of the need to pull the production tubing dramatically reduces costs associated with plugging particular sections of a well. Different sections of a well might need to be plugged because of, for example, water breakthrough, gas production, etc. Retrievable bridge plugs are also run to plug certain sections of a well in order to test different fluids flowing into the well at that location or above that location from shallower zones within the wellbore. Such bridge plugs generally include a lower valve which provides a seal, blanking off a section of mandrel so that a packer element, also contained within the retrievable bridge plug, can be inflated. The packing element provides for the plugging off of the selected sections of the well. The construction and use of a conventional bridge plug is considered known to one of ordinary skill in the art. Such bridge plugs are commercially available from many sources including Baker Oil Tools, Houston, Texas (Product Nos. 340-10 and 330-72).

SUMMARY

The above-identified drawbacks of the prior art are overcome, or alleviated, by the intelligent bridge plug system of the invention.

The present invention avails itself of the benefits evident in conventional retrievable bridge plugs and further provides a method and apparatus for accurately setting the inflation pressure of a retrievable bridge plug and verification of that setting. The apparatus of the invention is a thru tubing bridge plug having downhole instrumentation and employing an electric wireline setting tool such as that disclosed in co-pending U.S. Serial No. 60/123,306, filed March 5, 1999, the entire contents of which is incorporated herein by reference. The device further comprises several sections of a retrievable bridge plug and several downhole sensors. The sensors are worked into the tool preferably in a sensor module which is a part of the retrievable bridge plug assembly. The sensor module is located in different sections of the tool for different embodiments as disclosed hereinbelow. The tool of the invention preferably measures element inflation pressure, temperature inside the packer and the annulus temperature as well as pressure uphole of (above) and downhole of (below) the packer. These parameters of the well may be used to ensure a proper setting of the inflatable element and thereby ensure that the bridge plug operates as intended. The invention provides a superior advantage over the prior art for many reasons including that the temperature of the inflation

fluid is nearly always cooler than the temperature downhole. If a packer is fully inflated with relatively cooler fluid, the thermal expansion of that fluid subsequent to filling could rupture the element. Such occurrence could be problematic and would preferably be avoided. The present invention provides the means to avoid such a condition and also will provide a high degree of confidence that the inflatable element is properly inflated every time the bridge plug is employed.

It is also important to note that one of the key points in measuring pressure below the bridge plug is to determine how the well is responding to the plug. This is an important benefit of the invention not heretofore available; comparing pressure above the plug with pressure below the plug which provides information about whether or not a zone has been effectively shut off and whether or not the packer has achieved a good seal. The existence of leaking through the casing or through fractures in the formation, etc. would be identified by comparing the above and below pressure. Moreover, the comparison indicated above provides information about whether or not pressure below a plug is being adversely affected by other wells in a situation where production wells and injection wells are operating in the same field. Furthermore, by monitoring all three of above the plug pressure, below the plug pressure and element inflation pressure verification can be obtained that the inflation pressure ratings for the element being employed have not been exceeded.

IN THE DRAWINGS

FIGURES 1-5 are an elongated view of a cross-section with a first embodiment of the invention; and

FIGURES 6-10 are an elongated view of a cross-section of a second embodiment of the invention.

DETAILED DESCRIPTION

Referring to Figures 1-5, a first embodiment of the invention is illustrated. It will be appreciated by one of ordinary skill in the art that Figures 1 and 2 and Figures 4 and 5 depict portions of the inventive bridge plug that are identical to a prior art bridge plug commercially available from Baker Oil Tools, Houston, Texas, under Product Nos.340-10 and 330-72. Since these portions are very well known to the art, a detailed description thereof is not necessary to a full understanding of the invention. For orientation and clarity, one of skill in the art will recognize upper valve sleeve 12, valve shaft 14 and equalizing mandrel 16 in Figure 1. In Figure 2, bumper housing 18 and associated components will be recognized.

Referring now to Figure 3, the sensor module 30 of the invention is illustrated. Sensor module 30 is important to the function desired in the present invention since it houses all of power, telemetry and sensor assemblies. Module 30 is essentially "cut into" the conventional tool in the position, in this embodiment, illustrated by Figures 1-5. Where bumper housing 18 would be connected to collet sub

20 in a prior art tool, the sensor module 30 is connected therebetween. It is important to note that collet sub 20 is modified in the invention to provide pressure paths which allow the sensing desired in the invention to take place. Poppet housing 22 is also modified, again to provide a pressure path for the sensing desired in the invention. Pressure is measured at the back side of the poppet to obtain accurate element pressure. The balance of the tool in this embodiment, referring to Figures 4 and 5 is conventional. One of skill in the art will recognize spring housing 24 connected to poppet housing 22 and element 26 connected to spring housing 24. Guide 28 is shown at the downhole end of the tool at the right side of Figure 5.

Referring back to Figure 3, the detail of the invention is discussed. At the box thread 32 of bumper housing 18, an uphole end of sensor module 30 is provided with a pin thread 34. The pin thread 34 is actually cut on a mandrel 36 of sensor module 30. Mandrel 36 is connected at its downhole end at pin thread 38 to collet sub 20 via box thread 40. Mandrel 36 is made pressure tight between tubing pressure and exterior wellbore pressure by o-rings 42 and 44 on the uphole and downhole ends thereof, respectively. Since sensitive electronic equipment must be delivered to the downhole environment in this tool, it is necessary to create a sealed chamber which may be atmospheric or hydraulic fluid filled. The chamber is numeraled 46 and is formed annularly between mandrel 36 and sleeve housing 48.

Sleeve housing 48 shares an o-ring with mandrel 36 at 42 and is provided with an additional o-ring 50 at an outer surface of collect sub 20. Chamber 46 is filled, in the invention, with a transmitter 52 locked in a desired position as shown by locking ring 54 which is threadedly connected to mandrel 36 at thread 56. Transmitter 52, preferably a piezo ceramic transducer, is connected via contacts (not shown) to an electrical control module with signal receiver 60 which is connected to battery pack 58. The control module regulates power to the transmitter 52, receiver 60 and the pressure transducers. Typically, a sine or square wave is sent to the transmitter to create either pulser or frequency acoustic outputs. It should be noted that several different control modules 60 or a single annular one may be employed. It is preferable to employ several modules 60 to reduce cost of manufacture. Constructing annular circuit boards for modules is expensive. The one or more modules 60 are connected to pressure transducers 62 and 64 which each monitor pressure in a different place via pressure pathways as shown. Pressure transducer 64 is "plumbed" to element pressure via pathway 66. Numeral 66 is repeated several times in the drawings to indicate the pathway. It will be noted that plug 68 is provided to close annular pressure from conduit 66. The plug is needed as a consequence of the manufacturing process for creating the pressure pathway 66 to element pressure.

In the case of pressure transducer 62, a pressure pathway 70 is provided which is left open

to annulus pressure at port 72. This transducer will sense annulus pressure above the element 26 (Figure 5). Differences between this pressure location and pressure below the element provides information about the setting of the element 26. Pressure below the annulus is measured by a similar set of components which cannot be seen in this drawing but will be understood to one of skill in the art by exposure to the shown component sets illustrated.

The tool as described is operable in several modes. One mode is a continuous data stream mode wherein the transmitter of the invention transmits acoustic (radio wave, electromagnetic wave, vibration or other) data at all times. As required or desired, a receiver is run in the hole to acquire the acoustic (radio wave, electromagnetic wave, vibration or other) signal and transmit data uphole. It should be noted that in situations where it is physically possible for the signal from the transmitter to reach the surface on its own, a receiver can be positioned at the surface. In another mode of operation of the invention, data is stored downhole until a signal to transmit is received by the tool. The signal could be generated at the surface and sent downhole or generated downhole by a receiver run in the hole for that purpose and for retrieving the data released.

In another embodiment of the invention, referring to Figures 6-10, a sensor module is differently configured and is located in a position within the otherwise conventional (except for

pressure pathways) bridge plug. Power and communication is provided through an inductive coupler coil discussed hereunder. In this embodiment, it is the uphole end of the tool which is most modified from its conventional cousin. For clarity, conventional components such as upper valve sleeve 80, lock segments 82, extension spring 84 and equalizing mandrel 16 are numbered. All other downhole components of the tool are conventional except for pressure pathways as noted in each of the figures. Pressure pathways are numbered in numerous places on the figures to provide an understanding to one of ordinary skill in the art as to the precise location thereof.

Focusing on the sensor module 90 in this embodiment of the invention, a sensor housing 92 has an uphole profile 94 to act as a fishing neck which functions as is known in the art. It will be appreciated that in prior art bridge plugs the fishing neck would be threaded directly to the equalizing mandrel 16. In the invention however, the equalizing mandrel 16 is threadedly connected to a porting sub 95 threadedly connected to sensor housing 92 at thread 96 and inner mandrel 98 at thread 100. The connections to porting sub 95, as stated, are sealed with o-rings 102.

A chamber 104 is created between inner mandrel 98 and sensor housing 92 which is sealed at the uphole end by o-ring 106 against an i.d. of sensor housing 92. Within chamber 104, electronic equipment similar to the first discussed embodiment is disposed. At least one electronic control

module(s) 108 is connected to pressure transducers 110 and 112. Pressure transducer 110 is connected to pressure pathway 114 which leads to annulus pressure downhole of the element 26. Plug 118 is required incident to the manufacturing process to prevent annulus pressure above the element 26 from being registered. Conversely, pressure transducer 112 measures pressure in the annulus uphole of element 26 through pressure pathway 120 which has access to annulus pressure through port 122.

In this embodiment, power is provided to the electronic components enumerated above via an inductive coupler coil 124. Power will thus be initiated at the surface or another remote power source. Since batteries are not the limiting factor on the life of this tool regarding testing of the parameters readable by the electronics therein, readings may be performed at any time, even many years after installation of the tool simply by providing power via a complementary coil (not shown). The sensors so powered can then communicate with a remote location or store data for later retrieval through the inductive coupler which in such an embodiment is employed as a communication link to a remote location. In one embodiment, the inductive coupler will not supply power at all but rather will act solely as a communications pathway and will function to extract data from the bridge plug whether the data is stored or is being actively recorded.

In yet another embodiment of the invention, transmission of data is forsaken entirely. More

specifically, a battery pack is utilized to power the tool and data is stored on the control module. This activity would continue as long as the battery pack supplies energy. Further the data storage could be continuous or could be at time intervals. Subsequently, when the bridge plug is pulled out of the well, the stored data on the control module could be downloaded for review and/or analysis. It will be appreciated that other sensors for parameters such as gamma radiation, temperature flow and other element or formation parameter may be added to any embodiment hereof.

While preferred embodiments have been shown and described, various modifications and substitutions may be made thereto without departing from the spirit and scope of the invention. Accordingly, it is to be understood that the present invention has been described by way of illustrations and not limitation.

CLAIMS

CLAIM 1. A downhole parameter sensing retrievable bridge plug comprising:

an inflatable element;

a sensor module connected to said inflatable element; and

at least one pressure transducer calibrated to sense one of element pressure, annulus pressure uphole of the element, annulus pressure downhole of the element.

CLAIM 2. A downhole parameter as claimed in Claim 1 wherein said at least one pressure transducer is a plurality of pressure transducers, each calibrated to sense one of element pressure, annulus pressure uphole of the element, annulus pressure downhole of the element.

CLAIM 3. A downhole parameter as claimed in Claim 1 wherein said at least one pressure transducer is connected to a pressure pathway provided in said retrievable bridge plug terminating at an access point to the target pressure.

CLAIM 4. A downhole parameter as claimed in Claim 1 wherein said at least one pressure transducer is in pressure reading communication with direct element pressure in said element.

CLAIM 5. A downhole parameter as claimed in Claim 1 wherein said bridge plug further comprises a

controller module operably connected to said sensor module.

CLAIM 6. A downhole parameter as claimed in Claim 5 wherein said control module stores data received from said at least one pressure transducer.

CLAIM 7. A downhole parameter as claimed in Claim 1 wherein said sensor module further includes a transmitter operably connected to said at least one pressure transducer, said transmitter having transmission capability.

CLAIM 8. A downhole parameter as claimed in Claim 7 wherein said transmitter transmits acoustically.

CLAIM 9. A downhole parameter as claimed in Claim 8 wherein said transmitter transmits by radio transmission.

CLAIM 10. A downhole parameter as claimed in claim 9 wherein said transmitter transmits by electromagnetic transmission.

CLAIM 11. A downhole parameter as claimed in Claim 5 wherein said control module continuously releases said stored data to a transmitter connected thereto.

CLAIM 12. A downhole parameter as claimed in Claim 5 wherein said control module upon command releases said stored data to a transmitter connected thereto.

CLAIM 13. A downhole parameter as claimed in Claim 5 wherein said control module at intervals of time releases said stored data to a transmitter connected thereto.

CLAIM 14. A downhole parameter sensing bridge plug comprising:

an inflatable element; and

a sensor sensing at least one parameter of the element, and a transmitter capable of transmitting information from said sensor to a remote location.

CLAIM 15. A downhole parameter sensing bridge as claimed in claim 14 wherein said plug further comprises additional sensors for at least one of the elements and the formation.

CLAIM 16. A downhole parameter sensing bridge as claimed in claim 15 wherein said sensors sense at least one of temperature, flow rate, pressure, gamma radiation, radio waves, electromagnetic wave or a combination with at least one of the foregoing.

CLAIM 17. A downhole parameter sensing bridge as claimed in claim 14 wherein said transmitter transmits one of acoustically, by radio wave, by electromagnetic wave, and by vibration.

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Application No: GB 0109632.0 **Examiner:** Eleanor Wade
Claims searched: 1-17 **Date of search:** 31 August 2001

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): E1F FKA, FKF

Int Cl (Ed.7): E21B

Other: Online: EPODOC, JAPIO, WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2349657	Baker Hughes (whole document)	-
X	US 5868201	Baker Hughes (col 24 line 3 to col 25 line 34 and fig 10)	1,5-10, 14-17
A	US 5417122	Casey et al. (whole document)	-

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.